THE QUATERNARY STRATIGRAPHIC RECORD AT LAKE EYRE NORTH AND THE EVOLUTION OF EXISTING TOPOGRAPHIC FORMS

By D. King*

[Read 9 June 1955]

SUMMARY

Fossiliferous Quaternary lacustrine deposits of the Lake Eyre Basin are exposed in escarpments along the margin of Lake Eyre North, and were intersected in shallow boreholes in the area. These are described in detail and their distribution shown on the geological maps.

The elevation of these earlier lake deposits above the present lake level, and their presence beneath a veneer of drift sand in the longitudinal ridges bordering the lake, have led to the conclusion that lake and dune formation are dual effects of wind erosion following desiccation in Early Recent times. Evidence is presented that a channelling effect of the wind played a major role in initiating dune development.

I. INTRODUCTION

The subject matter of this paper is largely based upon observations by the writer while taking part in a scientific expedition to Lake Eyre North organized and led by Mr. C. W. Bonython in May, 1953. The operational base for this expedition was located on the south-eastern shore of Lake Eyre North near the channel connection to Lake Eyre South, at a distance of some 25 miles by ill-defined track north-west of Muloorina Station homestead.

An area of approximately 800 square miles — partly occupied by featureless lake bed — was embraced by the detailed survey, using R.A.A.F. air photographs as base maps. An interesting succession of Quaternary sediments was discovered in cliffs at the lake margins, and was encountered in a series of bores sunk with a post-hole auger at a number of places in the lake bed. The investigation has revealed several significant facts relating to sand dune development which were not formerly appreciated, all of which substantiate earlier work of the late Dr. C. T. Madigan.

A subsequent study of air photographs of the whole Lake Eyre region provided additional physiographic material which is also incorporated in this contribution.

Some new place names used in the text were proposed by Mr. Bonython and approved by the Lands Department Nomenclature Committee (Report of the Lake Eyre Committee, 1955, p. 7).

The writer acknowledges the co-operation and assistance of Mr. Bonython in the field, and the use of survey measurements by a member of his party (Mr. W. Fenner). He is indebted to the Director of Mines of South Australia for the opportunity to accompany the expedition and for arranging preparation of the maps for publication. Meteorological data was kindly made available by Mr. B. Mason, of the South Australian Weather Bureau.

II. REGIONAL PHYSIOGRAPHIC SETTING

Lake Eyre is the largest of numerous salinas which are distributed throughout the semi-desert areas of South Australia. Lake Eyre North has a total coverage of some 3,100 square miles, and is connected by a narrow water-course known as Goyder Channel to the smaller Lake Eyre South. The lakes are bounded on the east and north by an extensive dune-covered plain comprising the southern portion of the Simpson Desert (Madigan, 1938, p. 504). Along the western margin is a highly dissected tableland, and bedrock hills of the

---

* Geologist, Geological Survey of South Australia.

Peake-Denison Ranges, and to the south and south-west are gibber plains with scattered dune ridges bordering the Northern Flinders and Willouran Ranges.

Lake Eyre North is approximately 25 feet below sea level (L.W.O.S.T. Port Adelaide) (Bonython, 1955) and the general elevation of large areas of the

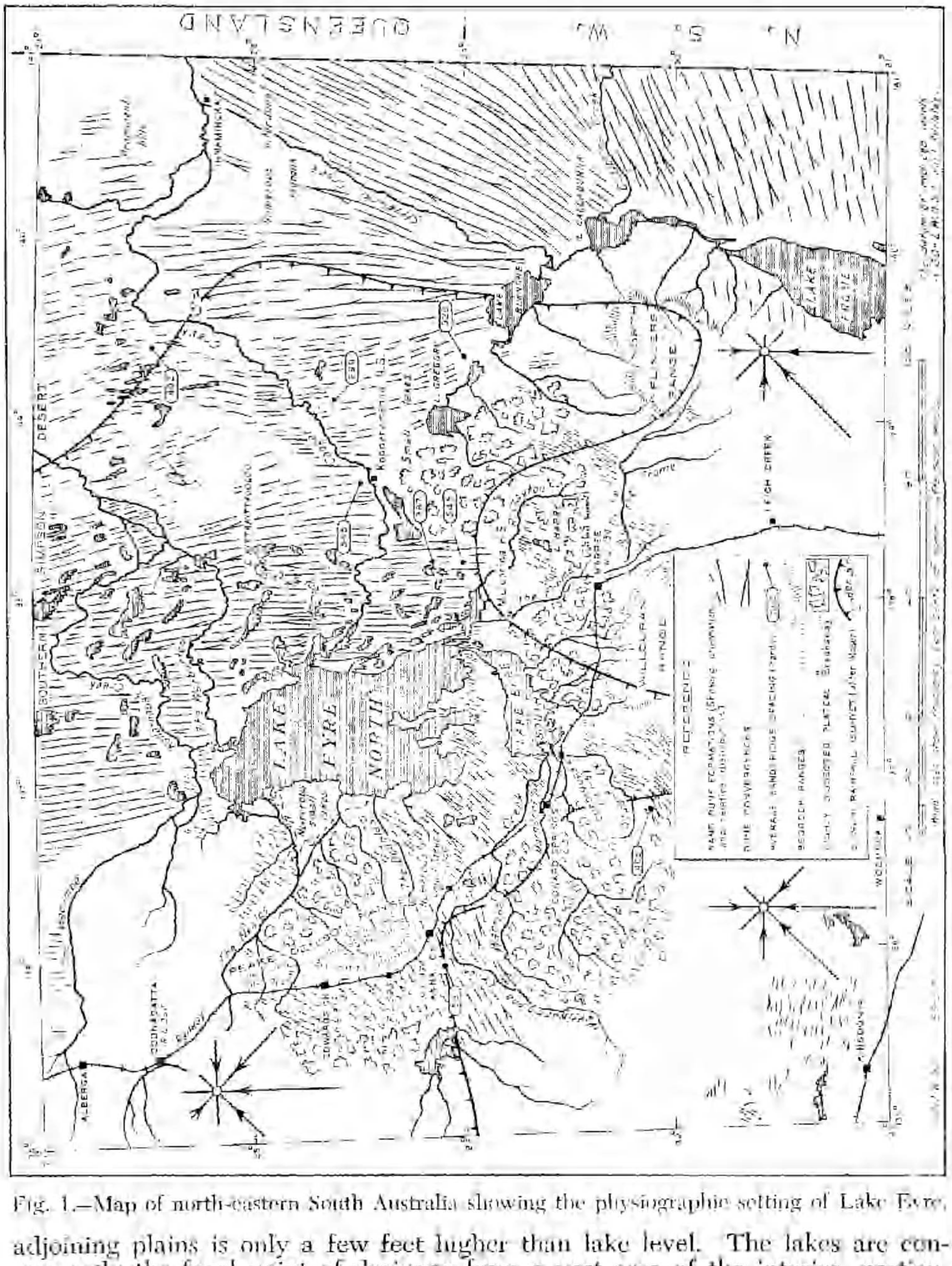


Fig. 1.—Map of north-eastern South Australia showing the physiographic setting of Lake Eyre.

adjoining plains is only a few feet higher than lake level. The lakes are consequently the focal point of drainage from a vast area of the interior, particularly from the north where the catchment includes higher rainfall areas in Central Australia and Queensland.

The main water-courses of the drainage system entering Lake Eyre are shown on Fig. 1. In normal years, any floodwaters from the north are dispersed and spent in smaller lagoons and deltas before actually reaching the lake, but in exceptional seasons such as experienced in 1949-50, Lake Eyre North may be completely flooded from these sources.

III. QUATERNARY STRATIGRAPHIC RECORD

The Lake Eyre region lies within the southern portion of the Great Artesian Basin. The broader geological features of Mesozoic and Tertiary rocks underlying the basin are described in earlier reports (Jack, 1915; Ward, 1946; Whittle and Chebotarev, 1952), and are chiefly based upon data from widely spaced boreholes sunk for water supply and petroleum exploration.

The area covered in detail during the present field survey comprises the south-eastern portion of the Lake Eyre Basin, where the Mesozoic and Tertiary rocks are covered by an appreciable thickness of Pleistocene and Recent lacustrine deposits.

The Quaternary sediments are now partly exposed in escarpments at the margin of Lake Eyre North due to subsequent desiccation and erosion, and were intersected in shallow boreholes sunk into the lake bed. The whole of the succession found in the area is fossiliferous, but the fauna present are a fresh to brackish-water association which cannot be relied upon for accurate age determinations. The lowest bed mapped is a gently folded dolomitic mudstone containing molluscan casts, and is regarded as Pleistocene in age. Overlying the dolomites unconformably are horizontally bedded gypseous clays containing ostracodes and oogonia of *Chara* and some native sulphur concretions, and capped by a deposit consisting almost entirely of shell remains and gypsum.

The Quaternary geology of the area as compiled from cliff exposures and borehole samples* is shown on the accompanying Fig. 2, and the following are descriptions of the main members of the sedimentary succession in ascending order:

PLEISTOCENE(?)

Dolomitic mudstones:

This member is a hard dolomitic mudstone measuring at least 20 feet in thickness and containing casts of shells (*Coxiella gilesi*) and thin lenticular laminae of green clay† and gypsum. It outcrops along the entire length of Hunt Peninsula at the southern end of Lake Eyre North, and farther to the east dips below the lake surface at an angle of about 5 deg. to the north-east. Samples of the dolomitic bed from three localities were chemically analysed by the Mines Department (under the direction of T. R. Frost) with the following results:

	Sample No. 1 Loc. C. cliffs per cent.	Sample No. 2 Loc. H. cliffs per cent.	Sample No. 3 Borehole. Madigan Gulf per cent.
Calcium oxide, CaO	24·14	29·54	23·94
Magnesium oxide, MgO	16·97	19·34	15·07
Acid insolubles	2·50	4·68	—

---

* The results of boring are shown diagrammatically in the cross-sections accompanying Figs. 2 and 3, and detailed logs are recorded in an official report filed with the Department of Mines.

† The clay mineral palygorskite has been identified in such clays from a borehole at Loc. C by L. Rogers, C.S.I.R.O., Division of Soils.

The result of a complete chemical analysis of Sample No. 3, together with exact details of its location, is contained in a paper by C. W. Bonython (1955 (a)), which is published in this volume.

The dolomite is fine-grained, and the uppermost layers are indurated by silicification (Plate 2, Fig. 1). Intraformational pellet structures and slump folding are widely developed and indicate their deposition in a shallow water environment. The dolomitic matrix of these sediments is probably a chemical precipitate resulting from periodic changes in salinity, in the same way as dolomite is forming at present in some other South Australian lagoons (Forbes, 1955).

EARLY RECENT(?)

(1) *Vari-coloured gypseous clays*

The dolomitic rocks are overlain unconformably by vari-coloured plastic clays passing upwards into pale green and brown sandy clays which attain a maximum observed thickness of up to 25 feet. The clays are exposed a few feet above lake level along the shores of Sulphur Peninsula, where they contain concretions of sulphur and gypsum (Bonython & King, 1955 (b)) and were penetrated by borings over a wide area in the south-eastern portion of Lake Eyre North. Samples from boreholes were examined by N. H. Ludbrook (1953, 1955) and found to contain numerous remains of the fresh-water plant *Chara*, ostracodes, and some foraminifera.

The unconformity at the base of the clays may be seen in the cliffs near Loc. D., where it is recorded by an eroded old surface of the dolomite, and elsewhere boreholes showed the presence of a thin limestone and quartz gravel bed resting upon the dolomite (Fig. 4).

The clay beds vary in colour both laterally and in depth due probably to variations in the state of oxidation of the iron content, but are essentially similar in composition and physical properties over their entire width. The main ingredient is extremely finely divided clay matter, shown by X-ray analysis to be largely amorphous and indeterminable. Other important constituents are evenly distributed rounded quartz grains, and thin partings of natural whiting. Gypsum crystals occur sporadically throughout the clays and in the lower horizons there are interstratified thin beds of crystalline gypsum. Samples taken from the lake bed develop an efflorescent coating of salt on drying, as previously described by Fenner (1952).

EARLY RECENT(?)

(2) *Gypseous shell beds*

The uppermost beds consist mainly of fragile shell remains (*Coxiella gilesi*) loosely embedded in fine siliceous and gypseous sand and clay, and interstratified with layers of gypsum crystals (Plate 1). In most places along the shoreline these beds have been removed by wind erosion and are only locally preserved where protected by drift sand deposits.

A complete section of the shell beds may be observed in the low shoreline cliffs adjacent to Shelly Island (Loc. M) where they are 4½ feet thick, and the uppermost bed is elevated approximately 36 feet above the level of the margin of Lake Eyre North. A layer of massive crystalline gypsum one foot thick, featured by strongly ripple-marked partings, underlies the shell remains. A detailed description of the section exposed at this locality is shown in Table 1.

Other outcrops of the shell beds are known on the eastern side of Sulphur Peninsula (Loc. S.E.), on the western side of Price Peninsula (Loc. A.), and in the upper levels of a small butte which rises prominently above the featureless limestone plain south-west of Shelly Island. All are elevated approximately 30 feet above the present lake surface.

Environment—Throughout this record the fossil evidence suggests predominantly brackish water conditions with periods of desiccation which gave rise to deposition of crystalline gypsum beds (and salt), and the temporary extinction of fish and invertebrate fauna. The lithology of the sediments is consistent with deposition in a permanently inundated, but gradually receding, inland lake basin — "Lake Dieri" (Fenner, 1952). No evidence was found to support earlier generalizations that there may have been a connection between Lake Torrens (approx. 100 feet above sea level) and the head of Spencer Gulf coeval with varying sea levels of the Pleistocene (David, 1932).

TABLE 1

DETAILED DESCRIPTION OF SUB-RECENT GYPSEOUS SHELL BEDS

Location M

LAKE EYRE NORTH

Situation—Peninsula on southern shore of Lake Eyre adjacent to Shelly Island. Approx. 6 miles W.S.W. of Sulphur Point.

A.R.L.[*] of top of section = 136.

Ft. In. Ft. In.	
0 0 – 1 10	Shells (*Coxiella gilesi*) embedded in fine gypseous sand. Siliceous grit and limestone pebbles. Uppermost layer forms flat pavement, partly covered by drift sand.
1 10 – 1 11	Crystalline gypsum rosettes.
1 11 – 2 3	Shells (*Coxiella gilesi*) embedded in fine gypseous sand and siliceous grit with narrow clay partings. Clusters of gypsum crystals.
2 3 – 2 7	Pale grey clay with a few shells (*Coxiella gilesi*).
2 7 – 2 10	Shell bed (*Coxiella gilesi*) in fine gypseous matrix.
2 10 – 2 11	Pale grey clay.
2 11 – 3 1	Shells (*Coxiella gilesi*) and fish vertebrae in fine matrix of sandy clay.
3 1 – 3 4	Grey clay and fine sand. Clusters of shells (*Coxiella gilesi*) in places.
3 4 – 3 6	Very fine white siliceous sand.
3 6 – 4 0	Shells (*Coxiella gilesi*) embedded in very fine pale grey siliceous sand.
4 0 – 4 1	Grey clay with some gypsum.
4 1 – 4 2	Pale grey fine siliceous sand—odd shells (*Coxiella gilesi*).
4 2 – 4 3	Shell (*Coxiella gilesi*) fragments in light sand and rounded quartz grit.
4 3 – 4 4	Fine pale grey siliceous sand.
4 4 – 4 4½	Clay with gypsum.
4 4½ – 4 6	Fine pale grey siliceous sand with shell fragments (*Coxiella gilesi*) near top.
4 6 – 4 10	Grey clay and abundant gypsum.
4 10 – 6 6	Section covered by drift.
6 6 – 7 6	Bed of massive crystalline gypsum with ripple-marked surfaces.

[*] Arbitrary Reduced Level—see Bonython (1955 (a)).

The deposition of the shell beds marks the final desiccation of the Pleistocene—Early Recent(?) lake, which was followed by the introduction of dominantly erosive agencies which it will be shown were largely responsible for the sculpturing of existing topographic forms.

IV. THE SAND FORMATIONS

The sand ridge formations which are so strongly developed beyond the eastern and northern margins of Lake Eyre — within the southern limits of the Simpson Desert — have been described in considerable detail in a series of contributions by Madigan (1929-1946). The area embracing the north-eastern portion of the State has since been covered by R.A.A.F. air photography (1945 and 1948), which together with ground observations during the present investigation, has provided an opportunity for additional research on the sand formations over large areas lying beyond the limits of Madigan's surveys.

The distribution and orientation of the dune ridges over a wide area surrounding Lake Eyre are shown on the topographical map (Fig. 1). An analysis of present day wind records from weather stations at Oodnadatta, Leigh Creek and Woomera is also presented on this map.*

The dunes of the Lake Eyre region are consistently of the longitudinal (or seif) type, as described by Bagnold (1941, p. 189). East of Lake Eyre, the ridges are aligned meridionally and evidently retain this orientation for several hundred miles to the north (Madigan, 1946). South-west of Lake Eyre there is a gradational change in dune trend from a dominant east-north-east direction near the lake to approximately east-west in the area west of the Central Australian Railway. A similar but opposing swing from northerly to easterly is also a marked feature of the dune pattern in the Lake Frome Plains, to the south-east of Lake Eyre.

The sand dune belts and individual ridges have the following characteristics:

1. It may be generally stated that the degree of completeness to which the dune topography has developed increases gradually to the north-east. The dunes south-west of Lake Eyre, for example, are broad and ill-defined sand strips which are of approximately equal width to the intervening troughs (Plate 4, Fig. 1). Towards the Simpson Desert, the definition and dimensions of the ridges increases, and they stand out in bold relief from the considerably wider interdune corridors (Plate 4, Fig. 2).

2. An outstanding feature of the dune morphology is the widespread occurrence of dune convergences, despite the otherwise rigid parallelism of the formations. These are usually represented in ground plan by an assymetric and inverted Y, and in every case the point of convergence is directed in the north to east quadrant, depending on the dune trend in the particular area.

3. Individual ridges have been observed to exceed twenty miles in length (Lat. 29°00'S.; Long. 138°15'E.) and may be much longer in places. It is only rarely, however, that dunes persist for such distances without converging and becoming composite formations.

4. The lateral spacing of the dunes is variable, but systematic, and appears to increase in a direct proportion to the height of the formations. The average dune spacing at a number of arbitrarily selected localities throughout the region (as measured from air photographs) are recorded on the topographic map (Fig. 1). These figures indicate a range from 3 to 33 dunes to the mile, and a usual spacing of about one-quarter mile.

5. The height of the dunes in areas examined by the writer is of the order of 40 feet. Madigan (1946, p. 48) reports that some in the central Simpson Desert are about 100 feet high.

6. In cross-section, the ridges are slightly asymmetric, with the steepest side to the east or south — according to trend.

7. The main mass of the dunes, and the interdune valleys, are now fixed by a stunted psammophytic vegetation (Crocker, 1946, p. 249). However, in many cases the dune crests consist of "live" sand which is modelled into minor structures by wind storms without any appreciable drift. A particularly common result of recent wind activity are successions of small fulje-like hollows along the crest of the ridges, giving rise to a characteristic "ribbed" or "plaited" structure (Plate 3).

A series of boreholes sunk into the sand formations at the south-eastern margin of Lake Eyre North (Price Peninsula) indicates that the longitudinal ridges in this area are only superficially formed of drift sand. The main mass of each ridge is composed of buried lacustrine deposits, including the Early Recent(?) shell beds and clayey sand horizons which were observed in some shoreline cliffs and are described in the preceding section. In the interdune corridors, the same beds have been removed by erosion and the surface soil is underlain by laminated clays of a lower stratigraphic level.

---

* The wind roses have been especially prepared to include only summer afternoon winds of greater velocity than 10 m.p.h. Such conditions are considered to be most favourable for shifting sand.

Details of the internal structure of the dunes as provided by boring are shown on the accompanying Fig. 3, on which surface levels and borehole logs are accurately recorded at an exaggerated vertical scale.

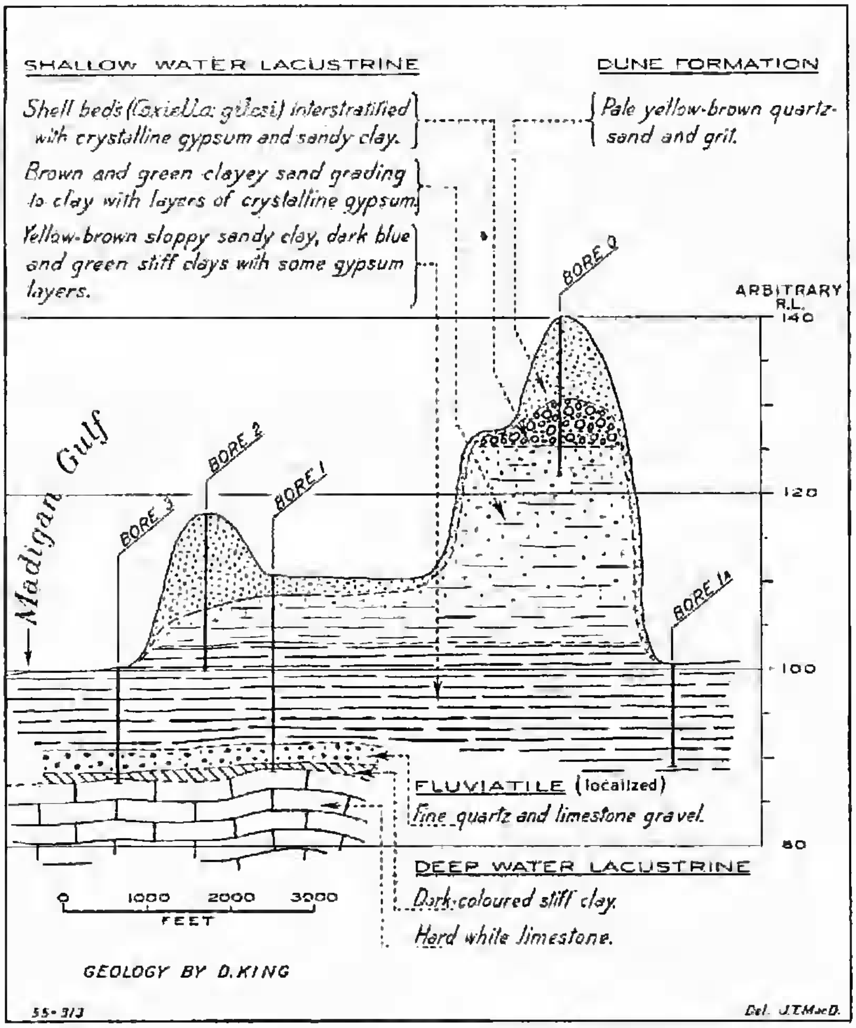

SHALLOW WATER LACUSTRINE
Shell beds (Coxiella gilesi) interstratified with crystalline gypsum and sandy clay.
Brown and green clayey sand grading to clay with layers of crystalline gypsum.
Yellow-brown sloppy sandy clay, dark blue and green stiff clays with some gypsum layers.
DUNE FORMATION
Pale yellow-brown quartz-sand and grit.
BORE O
ARBITRARY R.L.
140
120
100
80
Madigan Gulf
BORE 3
BORE 2
BORE 1
BORE 1A
FLUVIATILE (localized)
Fine quartz and limestone gravel.
DEEP WATER LACUSTRINE
Dark-coloured stiff clay.
Hard white limestone.
0
1000
2000
3000
FEET
GEOLOGY BY D. KING
55-313
Del. J.T.MacD.

Fig. 3.—Diagrammatic geological section through sand ridges on S.-E. margin of Lake Eyre North.

The borehole at Position O is located on the crest of a prominent longitudinal dune at an elevation of 40 feet above the margin of Lake Eyre North (A.R.L. 100) and 30 to 40 feet above the interdune depressions on either side. In this borehole, aeolian sands were found to give way to gypseous shell beds at 9½ feet depth. At a depth of 15½ feet, the bore penetrated grey sandy clays and sand, and bottomed in a bed of crystalline gypsum at 22 feet above present lake level.

Screen analyses were carried out on samples recovered from Borehole O with the following results:

Sample No.	Depth of Sample		Sizings B.S.S. (By weight)						
	From	To	+18	−18+30	−30+60	−60+100	−100+200	−200+300	−300
1	0′ 0″	0′ 0¼″	10·25	34·5	32·5	6·75	4·0	0·5	11·5
2	0′ 0¼″	8′ 0″	2·5	3·0	33·0	19·5	32·25	6·25	3·5
3	8′ 0″	9′ 6″	2·0	7·5	31·0	13·5	21·5	8·5	16·0
4	9′ 6″	13′ 6″	9·5	16·25	29·25	12·0	18·0	8·5	6·5

Sample No. 1 is representative of a noticeably coarser quartz sand which characteristically forms a thin surface layer on the dune ridges.

Samples Nos. 2 and 3 consist of well-sorted siliceous sand from the main mass of the aeolian deposits. Grain diameters mostly lie in the −30 +200 grade, between 0·25 and ·076 mm., and are comparable with samples taken from longitudinal dunes elsewhere in the region (Carroll, 1944).

Sample No. 4 comprises the sandy matrix of the underlying shelly lacustrine deposits. As might be expected in this case, the screen analysis indicates a much lesser degree of sorting than featured by the wind blown sands.

At a number of localities along the south-west shores of the lake the coastal dune sands have been observed to largely comprise seed gypsum and shell fragments. These gypseous dunes are well exposed along the western margin of Sulphur Peninsula (Fig. 2), where they were previously noted by Madigan (1930). The base of the dunes corresponds with the present level of the lake, indicating that they are a quite recent shoreline feature.

V. EVOLUTION OF THE TOPOGRAPHIC FORMS

Lake Eyre North is approximately 25 feet below L.W.O.S.T. Port Adelaide (Bonython, 1955 (a)) and would be expected to have silted up to a considerable depth under the prevailing conditions of endoreic drainage. However, this is not the case as shown by the following conclusions drawn from the evidence presented in the preceding pages:

1. The occurrence of undisturbed Early-Recent(?) sediments in shoreline cliffs at an elevation of 36 feet above the lake bed shows conclusively that the evolution of the lake as it is today has actually involved erosion and removal of at least a corresponding thickness of earlier lake deposits.

2. Boring in the desert-sand formations along the south east shore of the lake has revealed that an appreciable thickness of Early-Recent(?) lake deposits has been removed from interdune valleys and lagoonal depressions, but practically the whole succession of these sediments is preserved in longitudinal ridges upon which the dune formations are superimposed.

It is evident from these erosional features that lake and dune development have proceeded concurrently. The excavation of the lakes and interdune corridors to their present level has involved — at least in the case of Lake Eyre* — the removal of older Quaternary lacustrine sediments by deflation, and the sandy fractions of the transported material have accumulated beyond the lake shores as longitudinal sand strips forming a veneer upon the crests of a corrugated land surface.

---

* It is, however, not overlooked that the Lake Eyre Basin as a whole is probably due to regional subsidence.

The direction of general sand movement is reflected by the orientation of the dune ridges, and by the remarkably regular shape and shore features of the lakes throughout the region. These all show the effects of sand migration towards the north and north-east, as outlined hereunder:—

The origin of the dune ridges appears to be satisfactorily explained by Madigan (1946) as due to dominant winds and sand movement parallel to the dune length (southerlies to south-westerlies), and periodical gusty side winds (chiefly westerlies). This conclusion is supported by the coincidence of regional dune trends with present day prevailing winds (Fig. 1), and by evidence of the internal structure of the ridges which indicates that no lateral movement of the main body of the ridges near Lake Eyre has occurred at any stage.

Pastoralists along the Marree-Birdsville track have observed that the spread of present day drift is towards the north (Madigan, 1946), and the same feature is also indicated by the aerial photographs (Plate 3). This occurs despite the fact that many of the dust-storms which are a feature of the summer season throughout this part of the State are directed from the north and must at least modify the rate of sand migration.

Several stages in the evolution of the longitudinal dunes and related claypans (or "blow outs") appear to be represented by existing topographic forms in marginal lake areas.

The initial channelling action of the wind may be observed to be operating on a small scale at the northern and north-western margins of all the lagoons, where there is an indefinite passage from lake bed to a bare and fluted wind-swept surface. To the leeward of the wind-swept areas, the drift sand accumulates as small transverse ridges which are grouped longitudinally and pass gradationally at increasing distances from the lakes into the normal longitudinal dune (Fig. 4).

These observations add credence to Bagnold's theory that the longitudinal dunes are a transition from earlier formed transverse formations, and may account for the "saw-tooth" profile of the ridges as described by Madigan (1946).

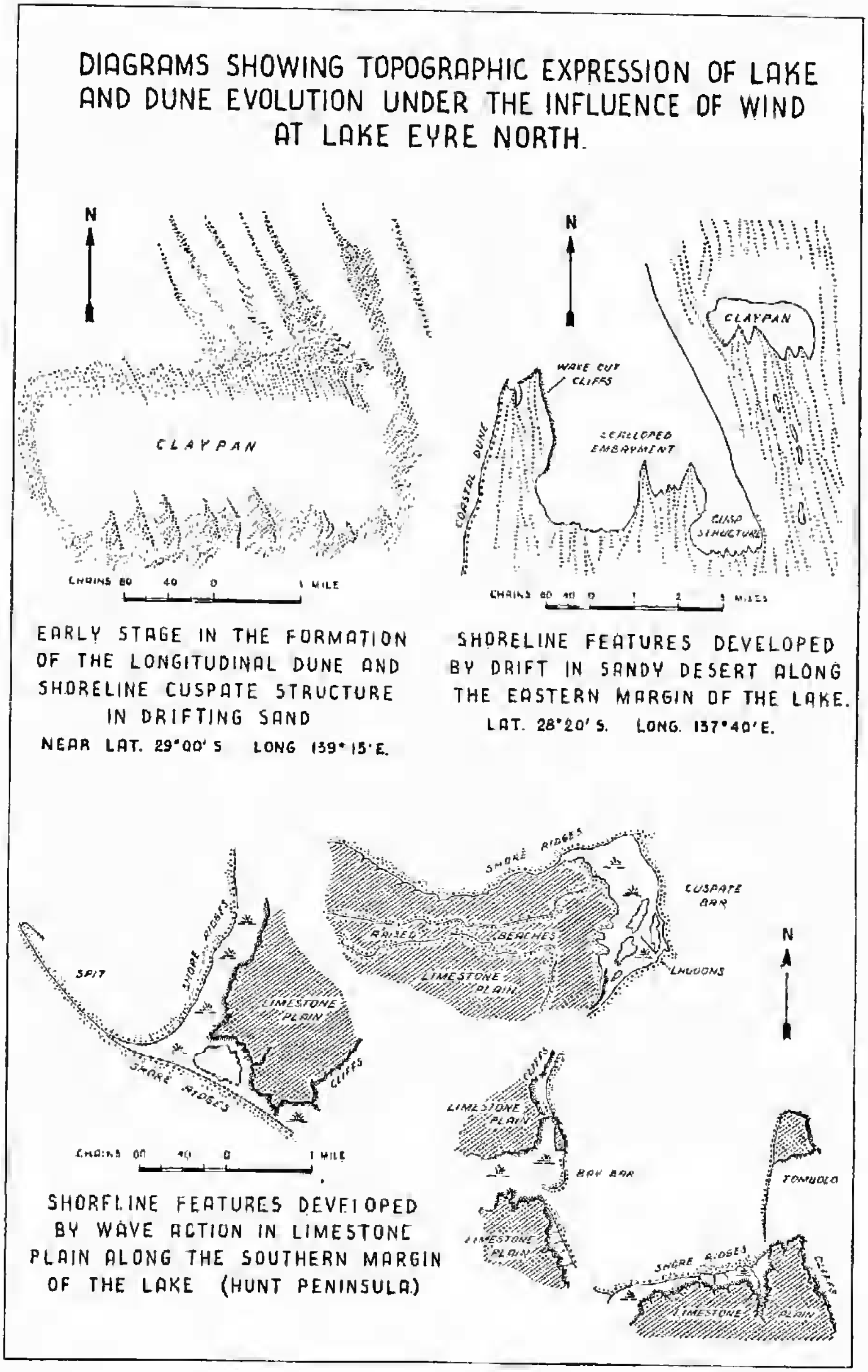
Once channelling by the wind commenced, the scouring effect would become increasingly effective in the hollows, and the rate of growth of the sand veneer on the intermediate ridges could be expected to increase accordingly. Once formed, the ridges with the greater protection of drift apparently survived the continued erosive effect of the wind, whereas others were reduced to the level of the interdune valleys — thus accounting for the observed variation of spacing with dune height.*

The dune convergences appear to be a result of the gusty side winds and their variable asymmetric forms suggest that both westerlies and easterlies were operative. The cross-winds were evidently capable of locally deflecting the leeward ends of some ridges where the cover of drift was of a minimum thickness and the ridges were of smaller bulk (Madigan, 1946). They may other-

---

* Prof. R. A. Bagnold comments on these generalisations in a personal communication of 10th December, 1955, as follows: "I find it difficult to accept that all the dunes in this area are really sand-covered relics of former lake deposits. One would like confirmatory data similar to Fig. 3 from other sites scattered over a large area, or over a long strip in the dune direction. You don't appear to have found any site where the non-aeolian core was exposed through some chance change in the local wind regime. If this is so, there would seem to be a strong tendency for the blown sand to creep *upwards* over everything: but the impression given by Fig. 3 is for the sand coating to be of even thickness everywhere — which I don't understand because it pre-supposes the sand to know how thick it is. It is, of course, just possible that either vegetation or thermal conductivity might explain this.

The prevalence of the Y-dune formations you have pointed out seems to fit in with the wind roses you give. There are two prevalent wind directions (or one very broad, indefinite one) and the directions of the two long arrows correspond well with the two arms of the Y in most places."


DIAGRAMS SHOWING TOPOGRAPHIC EXPRESSION OF LAKE AND DUNE EVOLUTION UNDER THE INFLUENCE OF WIND AT LAKE EYRE NORTH.

EARLY STAGE IN THE FORMATION OF THE LONGITUDINAL DUNE AND SHORELINE CUSPATE STRUCTURE IN DRIFTING SAND
NEAR LAT. 29°00′ S LONG 139° 15′ E.

SHORELINE FEATURES DEVELOPED BY DRIFT IN SANDY DESERT ALONG THE EASTERN MARGIN OF THE LAKE.
LAT. 28°20′ S. LONG. 137°40′ E.

SHORELINE FEATURES DEVELOPED BY WAVE ACTION IN LIMESTONE PLAIN ALONG THE SOUTHERN MARGIN OF THE LAKE (HUNT PENINSULA)

Fig. 4.

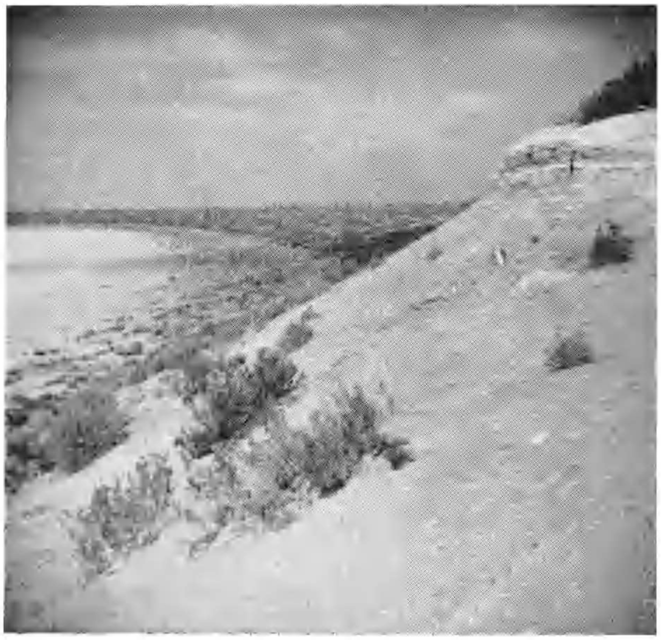


Fig. 1.—Shell beds (*Coxiella gilesi*) exposed at top of shoreline cliffs at the south-eastern margin of the lake (Loc. M.). These lacustrine sediments are elevated 36 feet above the general lake level.

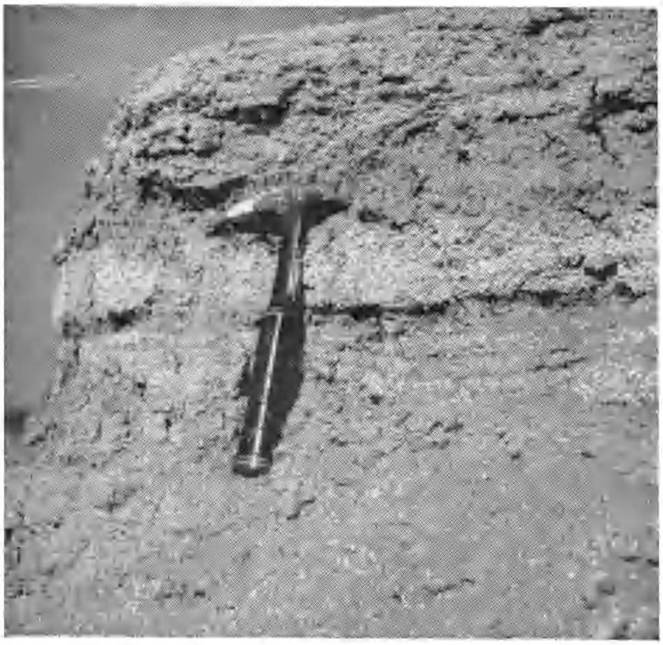


Fig. 2.—Near view of shell beds (*Coxiella gilesi*) at top of cliff section in the same locality as above.